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Title: Non-Destructive Assay (NDA) Uncertainties Impact on Physical Inventory Difference (ID) and Material Balance Determination: Sources of Error, Precision/Accuracy, and ID/Propagation of Error (POV)

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# **Non-Destructive Assay (NDA) Uncertainties Impact on Physical Inventory Difference (ID) and Material Balance Determination: Sources of Error, Precision/Accuracy, and ID/Propagation of Error (POV)**

James Wendelberger

8/23/2016

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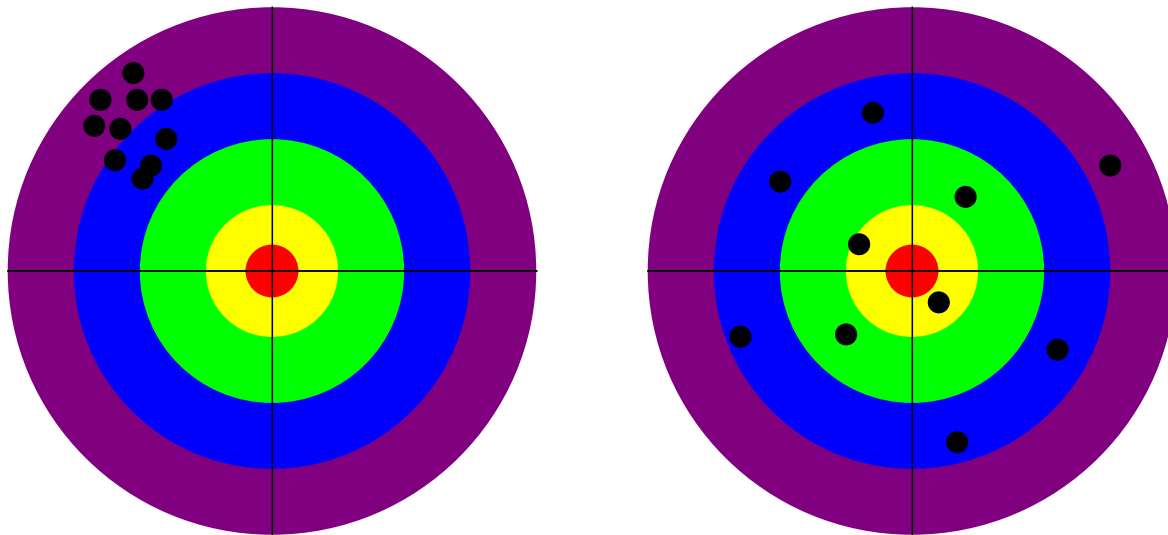
# Sources of Error for NDA Gamma Measurements

- Systematic Error
  - Absorption
  - Geometry
  - Detector Efficiency
  - Environment (Background)
  - Fundamental Physical Constants
    - Branching Ratio
    - Half Live
  - Unknown
- Random Error
  - Counting Statistics (Time duration of measurement)
  - Unknown

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# Precision and Accuracy Are Two Important Characteristics of Measurements

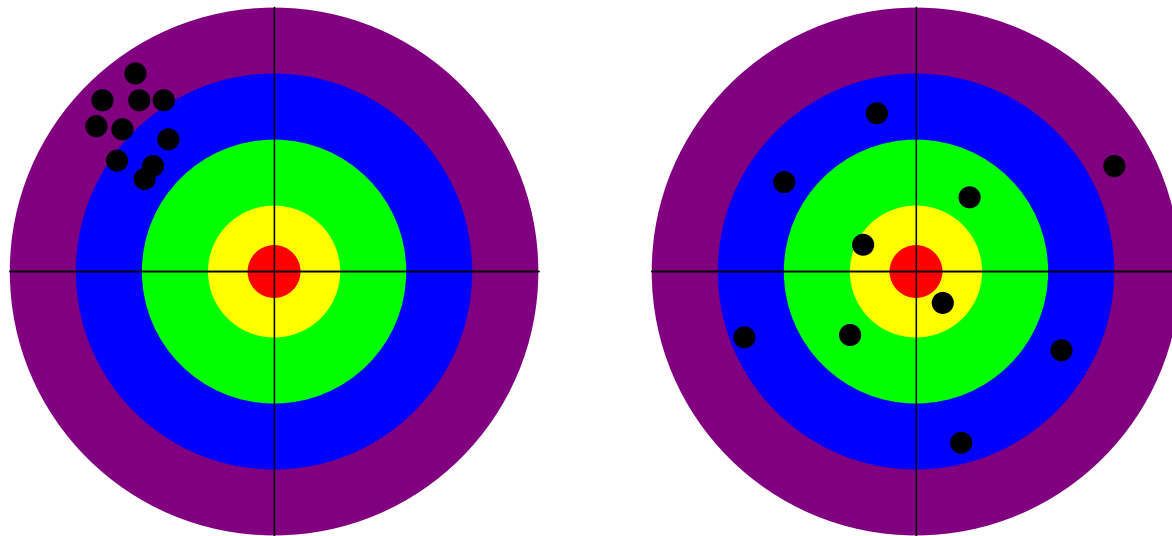
- If the process has little variation, it is said to be precise. Another term used is dispersion.
- If the process mean or average is close to the target center, it is said to be accurate. Another term used is unbiased.



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## Precision and Accuracy – continued.

- The shooter on the left has the least variation between shots and is thus more “precise.” This shooter’s shots are less dispersed.
- The shooter on the right is the most accurate. Although the shots are widely scattered, the mean or average is close to the target center.



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# Four Items Processed in a Material Balance Area During the Inventory Time Period

Item 1:

- 10% Relative Error
- Beginning Inventory = 100

Item 2:

- 5% Relative Error
- Beginning Inventory = 100

Item 3:

- 2% Relative Error
- Transfer In = 100

Item 4:

- 1% Relative Error
- Transfer In = 100

Processing



Item 1:

- 10% Relative Error
- Ending Inventory = 90

Item 2:

- 5% Relative Error
- Transfer Out = 95

Item 3:

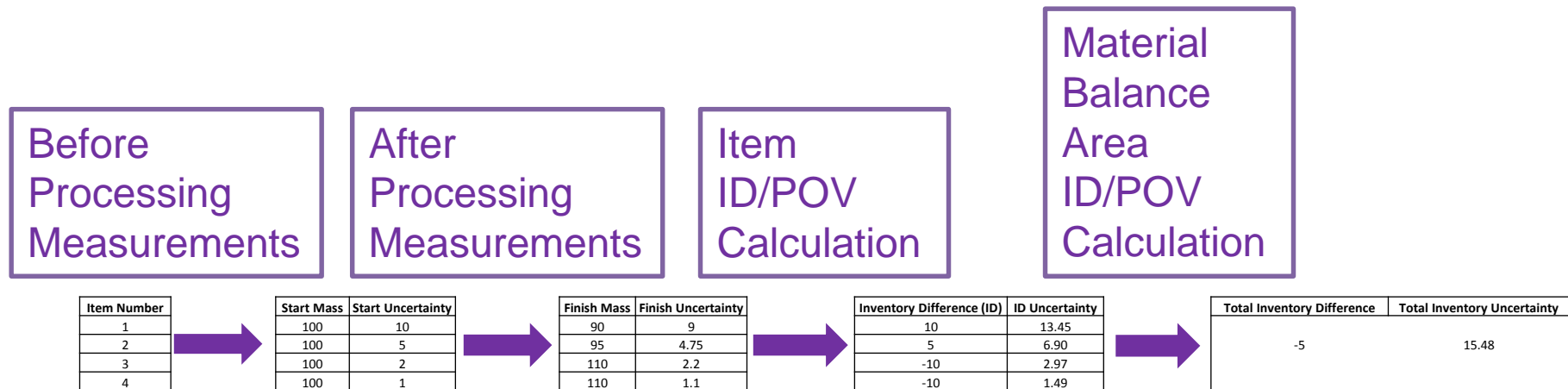
- 2% Relative Error
- Ending Inventory = 110

Item 4:

- 1% Relative Error
- Transfer Out = 110

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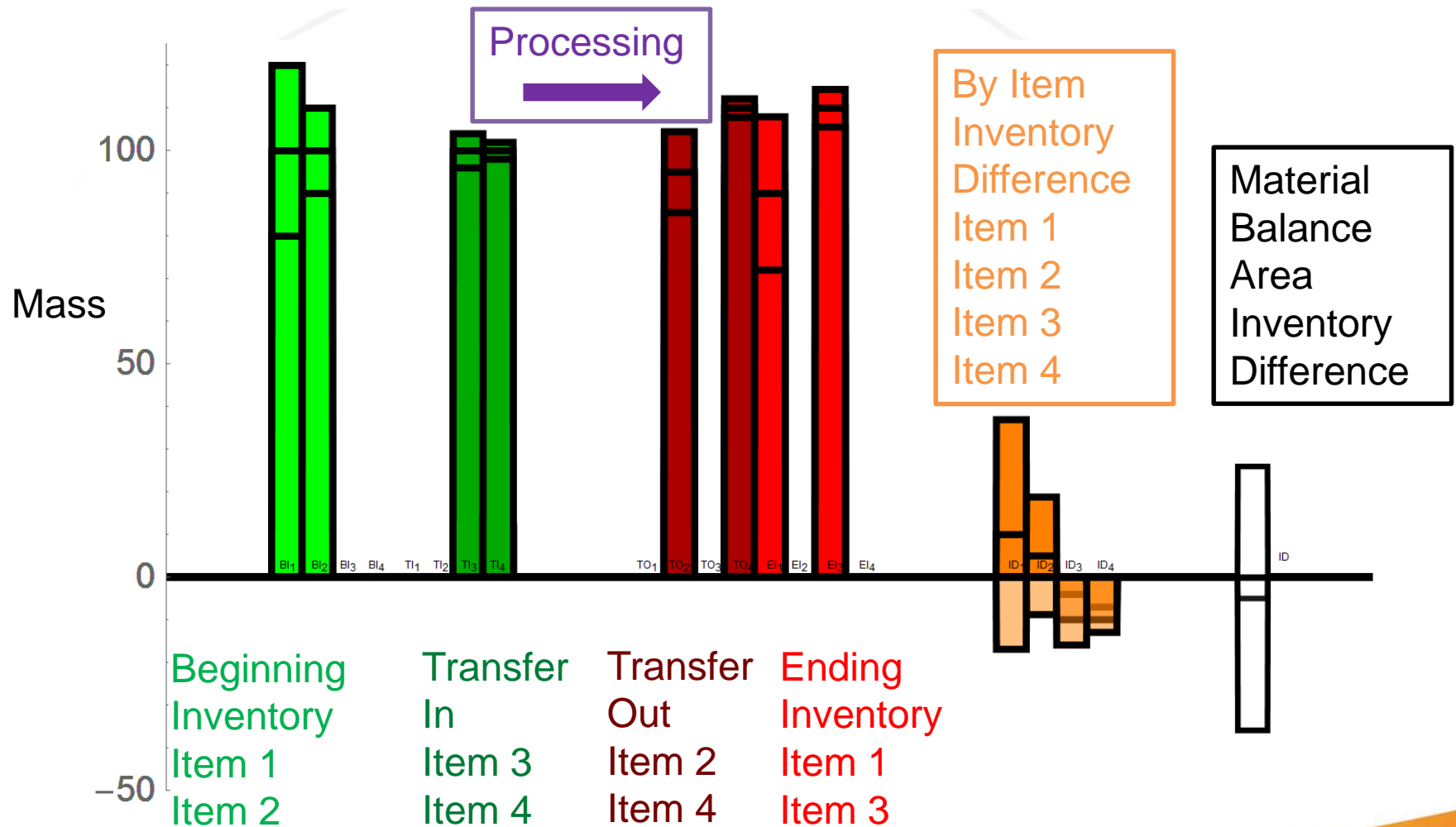
# Four Items Processed in a Material Balance Area During the Inventory Time Period



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# Inventory Difference and Propagation of Variance



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# Sum in Quadrature

Item 1: 10% Rel Error BI = 100, EI = 90

Item 2: 5% Rel Error, BI=100, TO=95

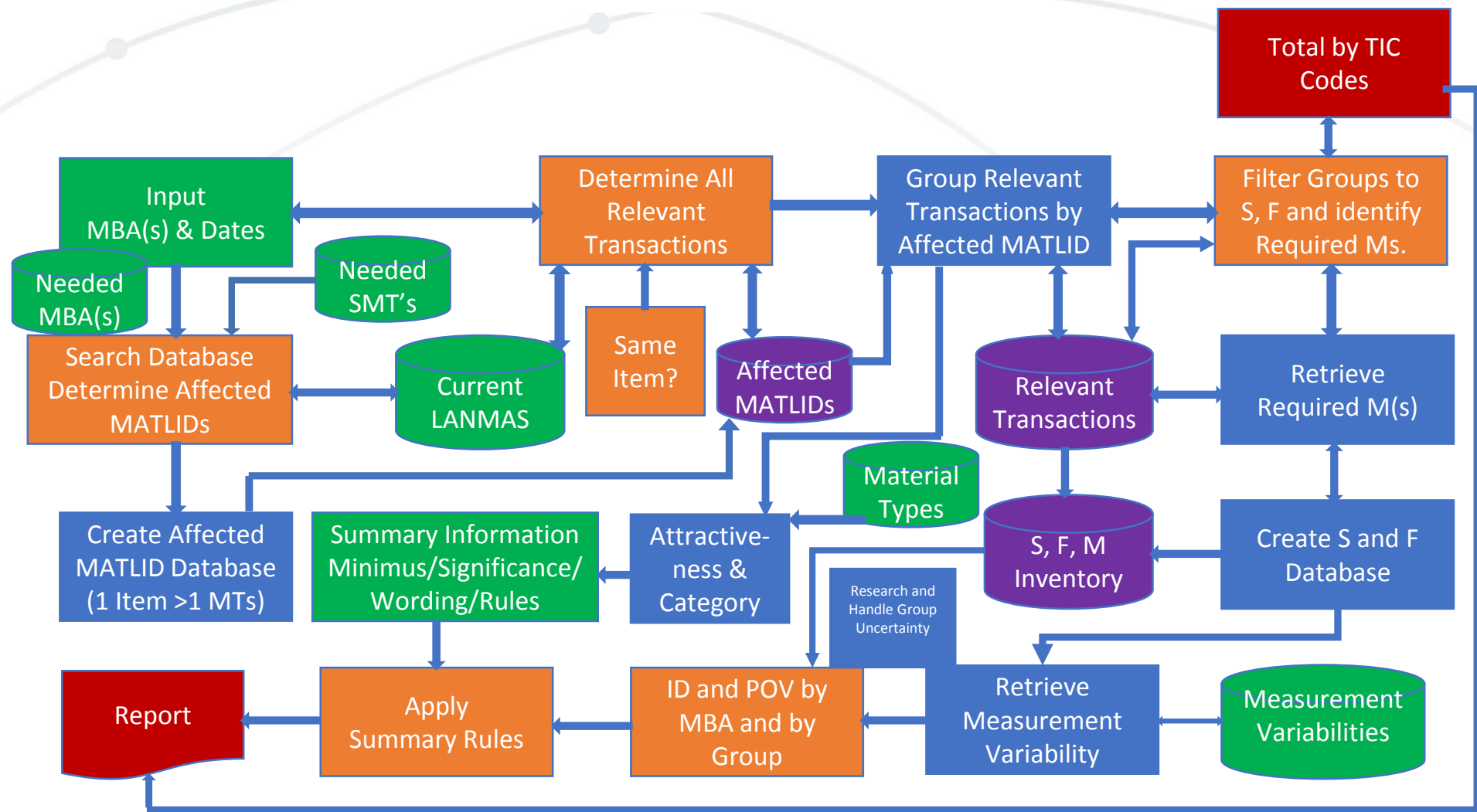
Item 3: 2% Rel Error, TI=100, EI=110

Item 4: 1% Rel Error, TI=100, TO = 110

- Item 1  $\sigma_1 = \sqrt{(.10 \times 100)^2 + (.10 \times 90)^2} = \sqrt{10^2 + 9^2}$
- Item 2  $\sigma_2 = \sqrt{(.05 \times 100)^2 + (.05 \times 95)^2} = \sqrt{5^2 + 4.75^2}$
- Item 3  $\sigma_3 = \sqrt{(.02 \times 100)^2 + (.02 \times 110)^2} = \sqrt{2^2 + 2.2^2}$
- Item 4  $\sigma_4 = \sqrt{(.01 \times 100)^2 + (.01 \times 110)^2} = \sqrt{1^2 + 1.1^2}$
- Overall ID  
 $\sigma_{ID} = \sqrt{10^2 + 9^2 + 5^2 + 4.75^2 + 2^2 + 2.2^2 + 1^2 + 1.1^2}$

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# Overview ID/POV Process



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Slide 9

# Overview ID/POV Process – Flowchart Item Descriptions

Flowchart Item	Description
Affected MATLID's	Unique material identification code.
Apply Summary Rules	Apply rules to actual id and uncertainty numbers for each material type and each material balance area.
Attractiveness & Category	What is the attractiveness of the material and category of the material balance area.
Create Affected MATLID Database (1 Item >1 MTs)	Database with affected material identification code and relevant material type(s) for each item.
Create S and F Database	For each item in the affected material id database determine the start (S) and finish (F) mass and uncertainty values.
Determine All Relevant Transactions	Determine transactions which are needed to determine the mass and uncertainty of each start (S) item.
Filter Groups to S, F and identify Required M's	Utilize the start and finish values and identify any items which remain to be measured (M).
Group Relevant Transactions by Affected MATLID	Group Relevant Transactions by Affected material identification code.
ID and POV by MBA and by Group	List inventory difference associated propagated variance for each material balance area and requested group of material balance areas for all materials in the inventory period.
Input MBA(s) & Dates	Determine which material balance areas inventory start date and inventory end date as well as the data retrieval date for which an inventory difference and propagation of variance analysis is to be performed.
Material Types	What are the material types of interest for any analysis?
Measurement Variabilities	Measurement variability to be assigned to each item.
Summary Information	What summary information is needed. This may for example include: throughput. What value of ID is practically significant, what level of statistical significance is important, what wording is used to communicate the status of each material type and what regulatory or other rules need to be followed?
Minimus/Significance/Wording/Rules	
Needed MBA(s)	Is information from other material balance areas needed in this analysis?
Needed SMT's	What summary material types are needed in this analysis?
Relevant Transactions	What transactions will determine the inventory difference and propagation of variance needed for the analysis?
Report	The report describing the analysis will be on a high level with summary information and more detailed fro drill down studies.
Research and Handle Group Uncertainty	How will groups of MBA's be handled? Treated as independent for propagation of variance purposes or pooled to eliminate any dependencies?
Retrieve Measurement Variability	For each start and finish measurement for items in the active inventory determine the measurement uncertainty to use and retrieve it from the database.
Retrieve Required M or M's.	For any item which is unmeasured at the end of the inventory period a measured value is needed. This is obtained my retrieving the measurement that is made after the inventory period ends and before the data retrieval date.
S, F, M Inventory	Database by active items containing the start mass (S), the finish mass (F), or an indicator that the item has not yet been measured (M) by the retrieval date.
Same Item?	An item may have multiple starts and finishes if it has been active, transferred out and been processed outside, transferred in and been processed inside the material balance area during the inventory period.
Search Database Determine Affected MATLID's	Given all of the information about the requested analysis determine the affected items and their unique material identification code.
Total by TIC Codes	Transactions are assigned a type inventory change (TIC) code. The TIC code may be used in the analysis to determine active items or to determine transactions which had no opportunity to gain or lose material.

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Slide 10